END
DATE
FILMED

10 80

DTIC

1.0

1.1

1.25 1.4 1.6

4.5
5.0
5.6
6.3

2.8
3.2
3.6
4.0

2.5
2.2
2.0
1.8

MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A
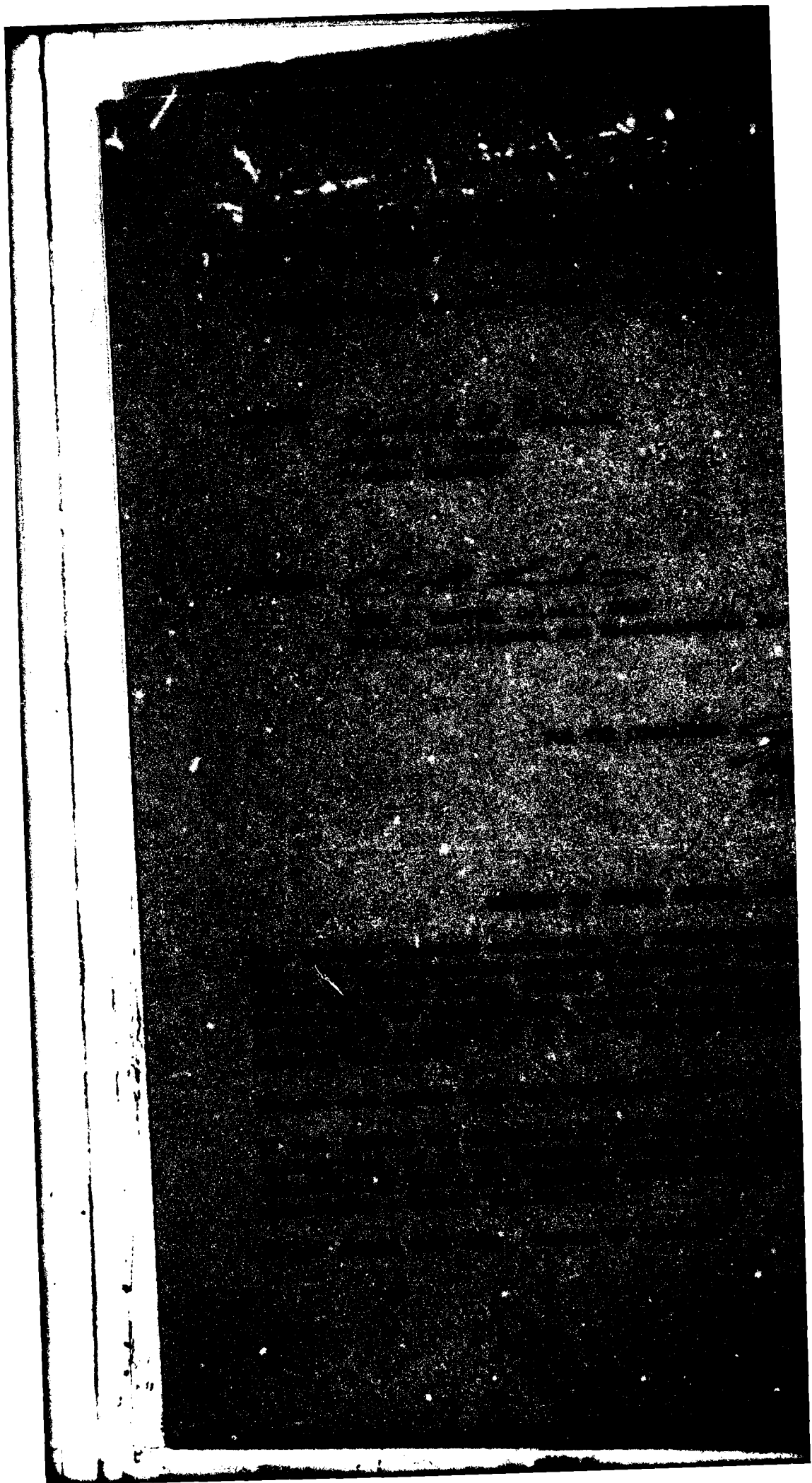
REPORT DOCUMENTATION PAGE	READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
RADC-TR-80-220	AD-A089198	

4. TITLE (and Subtitle)	5. TYPE OF REPORT & PERIOD COVERED
DLMS VOICE DATA ENTRY	Final Technical Report. 28 Sep 78 — 16 Nov 79
	6. PERFORMING ORG. REPORT NUMBER
	N/A

7. AUTHOR(s)	8. CONTRACT OR GRANT NUMBER(s)
Phillips B. Scott	F30602-78-C-0327

9. PERFORMING ORGANIZATION NAME AND ADDRESS	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
Threshold Technology Inc. 1829 Underwood Blvd Delran NJ 08075	64701B 43030032

11. CONTROLLING OFFICE NAME AND ADDRESS	12. REPORT DATE
Rome Air Development Center (IRAA) Griffiss AFB NY 13441	June 1980
	13. NUMBER OF PAGES
	41

14. MONITORING AGENCY NAME & ADDRESS (If different from Controlling Office)	15. SECURITY CLASS. (of this report)
Same	UNCLASSIFIED
	15a. DECLASSIFICATION/DOWNGRADING SCHEDULE N/A

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

Same

18. SUPPLEMENTARY NOTES

RADC Project Engineer: Richard S. Vonusa (IRAA)

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Voice Data Entry
Speech Processing
Word Recognition

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report describes the design, principles of operation, and performance characteristics of an Advanced Development Model of a voice recognition system (VRS) which can serve to input cartographic data to a computer. The completed system has been installed at the Defense Mapping Agency Aerospace Center (DMAAC) at St. Louis, MO, for evaluation and testing. The VRS is intended for use in entering by voice cartographic data to the Digital Landmass System (DLMS) Data Base. It

DD FORM 1473 EDITION OF 1 NOV 65 IS OBSOLETE
1 JAN 73

was designed to satisfy the DMAAC product specifications.

The VRS which was developed during this program has the quality of recognizing up to 248 separate words in syntactic structures. The system hardware includes equipment supplied by Threshold Technology Inc. (TTI) as well as government-furnished property furnished by RADC. The hardware is based upon the VIP-100 word recognition system sold commercially by TTI. Several ancillary hardware items not included in the basic VIP-100 configuration have been added to this ADM-VRS. These items include a flexible disk storage system, a magnetic tape unit, a video terminal, and a voice response unit.

The software developed for the VRS includes two complete stand-alone programs. One program, called CREATE, is used to define a syntactic tree structure for use by the other program called RUN. Each program operates independently and is stored on a flexible disk. Syntactic structures are referred to as "node plans" in the following paragraphs. The node plans are stored on flexible disks after being constructed by the CREATE program. Included with each node plan is a set of vocabulary word and prompting messages for both visual displays and for the voice response unit. Vocabulary word messages are those which are displayed in response to recognition of vocabulary words. Prompts are used to step the operator through a data input task. The CREATE program provides the means for changing any of these messages for a particular node plan.

Performance tests conducted at TTI disclosed an average system word recognition accuracy of just under 99 percent for five talkers. The recognition tests were conducted by the use of tape recordings. These tape recordings were made during a previous contract involving cartographic data entry. Each person spoke approximately 536 words after uttering five training repetitions. The test results were virtually identical to those obtained during the previous contract.

TABLE OF CONTENTS

i

LIST OF ILLUSTRATIONS

EVALUATION

The objective of this program is to develop a complete Advanced Development Model (ADM) capability for the Digital Landmass System (DLMS) Data Base using voice recognition technology.

A 248-word structured speaker-dependent voice data entry system was delivered to the Defense Mapping Agency Aerospace Center in St. Louis, MO. DMA analysts shall evaluate operational performance of the voice data entry system hardware and software based on accuracy and throughput and compare it to keyboard data entry and OPSCAN Form data entry.

Performance tests at the contractor's facility achieved a word recognition score of just under 99 percent for five talkers.

Voice data entry, especially in a hands & eyes busy environment such as when the DMA analyst is making photo-intensive measurements of cultural features through a stereoviewer, is the most efficient and least fatiguing method to enter data into a computer.

RICHARD S. VONUSA
Project Engineer

iii

Section I

INTRODUCTION

A.   Objective

The objective of this program has been to construct a voice
data entry system in the form of a complete Advanced Development Model
(ADM) word recognition system to be used by Defense Mapping Agency
Aerospace Center (DMAAC) for entering Digital Landmass System (DLMS) data
by voice to a computer at DMAAC in St. Louis, MO. The ADM is based upon
a highly accurate isolated-word, speaker-independent, large vocabulary
recognition system which includes a number of features and ancillary
devices to provide the maximum efficiency in the data entry process.

B.   Background

The DMAAC employs many cartographic analysts to derive and enter to
a computer source data from aerial photographic and intelligence material.
This data gathering process is used in the production of Off-Line Digital
Data Based to be used to support various weapon systems. The Off-Line
Digital Data Base is designed to contain cartographic features in digital
form with known geographic control. Each of these cartographic features
is identified with a descriptor code defining feature characteristics.
In the production of culture data for the DLMS, the cartographic analysts
examine maps or aerial photographs and enter to computers significant
culture data features and descriptors by means of Feature Analysis Data
Tables (FADT). Each significant cultural data feature is assigned a
Feature Analysis Code (FAC) number. This code number, together with a
series of descriptors is entered by hand on to the FADT tables. Later,
this data is keypunched for entry into a computer used for data reduction
and modification. This manual encoding operation interrupts the
cartographer's concentration in the performance of his or her analysis
and allows the entry into the processing of errors at several stages.
Errors can occur in the transcribing of FAC data by the analyst onto the
the FADT tables and later by transcribing by keypunch operators of this
data into the computer. It is necessary, because of the possibility of
transacribing errors at these stages, to later carefully verify all input
data before the digital data base is used in further processing. Any
means which can be developed to increase the efficiency of the analysis
and decrease the propensity of errors creeping into the process will be
a valuable adjunct to the production of the DLMS data base.

DMAAC has developed an alternate method of data entry which
substitutes optically scanned coding sheets. This method eliminates
the need for keypunching but does not eliminate verification and error
correction steps in the data processing. The use of the "Op-Scan"
coding sheets has resulted in negative analyst reactions because of
added eyestrain. It is difficult for many analysts to constantly shift
their vision from stereo viewers to the Op-Scan sheets and back again.

1

C.   The Use Of Voice For DLMS Data Entry

The most natural form of communication between a human and a machine is voice data input. Voice data entry in the DLMS cartographic application can provide a means for the cartographic analyst to enter data directly into the computer system used for the processing of the data without manual transcribing, keypunching, and other error-prone inter- mediate steps. A cartographer can simultaneously derive and enter by voice source data from the maps or aerial photographs. The use of voice data entry frees the hands of the analyst to concentrate on making accurate measurements of the culture features being examined. The analyst can enter all data by voice command without losing sight of the work surface. The current practice of entering the FAC data manually by pencil into the FADT table disturbs the concentration of the analyst in the performance of his or her task.

Threshold Technology Inc. (TTI) has developed under this program a Voice Recognition System (VRS) which can be used to explore the use of voice data entry (VDE) in the DLMS or other cartographic data entry applications. This VRS system has the capability of recognizing up to 248 separate words in syntactic structures. A software operating system has been included with the hardware to allow changes in the syntactic structure as DLMS requirements change. A default program structure has been supplied which is based upon the DMA publication, "Production Specifications for Digital Landmass System (DLMS) Data Base", dated July, 1977. The syntax module of the system software can easily be modified by keyboard entries.

In this report, system hardware and software details are explained in Section II. Section III outlines system accuracy tests, and Section IV includes conclusions and recommendations.

Section II

TECHNICAL DISCUSSION

A.   Introduction

The hardware and software features of the Advanced Development Model
(ADM) isolated-word Voice Recognition System (VRS) developed under this
contract are described in this section. This VRS system has the capability
of recognizing up to 248 separate words in syntactic structures. The
system hardware includes equipment supplied by Threshold Technology Inc.
(TTI) as well as government-furnished property furnished by RADC. The
hardware is based upon the VIP-100 word recognition system sold commercially
by TTI. Several ancillary hardware items not included in the basic VIP-100
configuration have been added to the VRS. Included in the complete VRS
are, in addition to the voice recognition module, a remote control unit, a
minicomputer, a video terminal, a teletype, two visual display devices, a
voice response module (VOTRAX) and two magnetic storage devices.

The voice input capability for data entry is effectively paralleled
by the video terminal keyboard. The priority interrupt structure has been
constructed so that in the event of an accidental attempt to type while
speaking, the voice input will be dominant.

The software developed for the ADM includes two complete stand-alone
programs. One program, called CREATE, is used to define a syntactic tree
structure for use by the other program, called RUN. Each program operates
independently and is stored on a flexible disk. Syntactic structures are
referred to as "node plans" in the following paragraphs. The node plans
are stored on flexible disks after being constructed by the CREATE program.
Included with each node plan is a set of vocabulary word prompting messages
for both visual displays and for the VOTRAX. Vocabulary word messages
are those which are displayed in response to recognition of vocabulary
words. Prompts are used to step the operator through a data input task.
The CREATE program provides the means for changing any of these messages for
a particular node plan.

An important feature of the system software is the use of special action
subroutines. These routines will perform a wide variety of functions
including data manipulation, message output, data output, branching from
one node to another, etc. The special action subroutines are associated
with individual words by action vectors (AV). Each action vector causes
a particular action subroutine to be activated in order to perform a specific
task. Action vectors are linked to vocabulary words when the structuring
of nodes is performed.

In the following paragraphs of this section, the system hardware and
software are described in detail. Appendix B includes a list of the action
vectors.

3

B.   System Hardware

The VRS is basically a VIP-100 isolated-word recognition system which
is described very briefly as follows. The VIP-100 is an adaptive system
which must be trained for individual talkers and words. Consequently, the
system is automatically adjusted or "tuned" to the voice characteristics
of different users in a very short time period. By the input of a small
number of training samples into the device to provide a reference set of
features, the decision criteria for each word in the vocabulary can be
modified or trained in an optimum manner. Thus, the system stores in
memory an individual reference set of word features for each word in the
vocabulary and for each talker in the system. After a cartographer trains
the system, new words spoken during normal operation are compared with the
stored references and a "closest fit" is selected as the recognized word.
The operation of the VIP-100 has been fully described in previous RADC
reports.[1]

1.   Hardware and Software Processors

The essential word recognition elements of a VIP-100 in general
and this VRS-ADM in particular are a speech preprocessor and a minicomputer.
In the VRS, as shown in the block diagram of Fig. 1, the preprocessor is
a TTI model 8040 and the minicomputer is a Data General Nova 2. The 8040
serves to extract significant acoustic features from input speech. The
Nova 2 minicomputer then compares these features with stored features for
words in the vocabulary in use. A decision as to which vocabulary word
was spoken is made by the computer according to a predetermined decision
algorithm.

For each spoken word, the 32 acoustic features, represented in a
binary form, are continuously inputted to the minicomputer from the
preprocessor through a special interface. These features together with
their times of occurrence are stored in a short-term memory. When the end
of the utterance is detected by the preprocessor, the duration of the word
is divided into 16 time segments and the features are reconstructed into a
normalized time base. The pattern-matching logic subsequently compares
these feature occurrence patterns to the stored reference patterns for
the various vocabulary words and determines the "best fit" for a word
decision. 512 bits of information (32 features mapped into 16 time segments)
are required to store the feature array of an utterance or reference pattern.

The Data General Nova 2 is a modern 16-bit minicomputer which includes
32K words of memory. It contains interfaces for all of the system I/O
devices including the special speech feature interface. The computer
also includes controller boards for the flexible disk system and for the
digital magnetic tape device.

[1]P.B. Scott, "Alpha/Numeric Extraction Technique," Tech. Report RADC-TR-
75-287 (B008303), dated November 1975.

Microphone

Voice Input-
Remote
Control Unit

TTI 8040
Speech
Preprocessor

ASR33
Teletype

VOTRAX
Voice
Response

Data General
Nova 2
Minicomputer

Lear-Siegler
ADM-3
Terminal

Loudspeaker

XEBEC XFD-100
Flexible Disk

Self-Scan
Display

Display
Interface

Data General
6026 Magnetic
Tape Unit

Zoom 240
Display

Equipment Cabinet
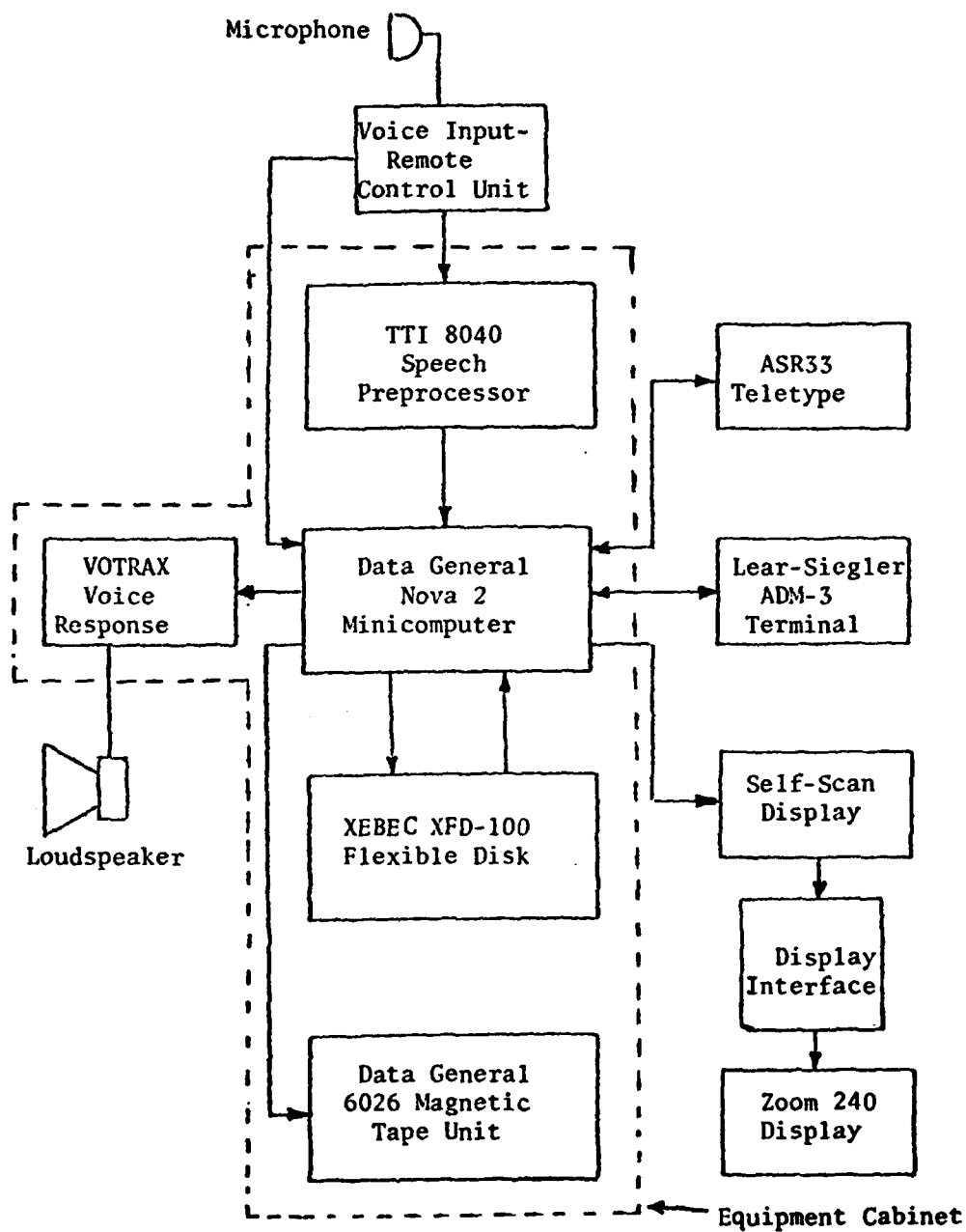
Fig. 1 Block Diagram of DLMS Voice Recognition System

5

2. Flexible Disk System

The flexible disk system, a Xebec model XFD-100, is interfaced to the Nova 2 computer as shown in Fig. 1. This device serves a multiple purpose in the VRS. It provides a method of storing the two stand-alone programs, stores alternate tree structures (called node plans hereafter), and stores the reference data for each speaker. This reference data is created by each speaker in the tuning or training phase which is necessary when each cartographer first uses the system. The flexible disk system also provides a bulk buffer storage for DLMS cultural data inputted by the cartographers. These data are, when convenient, written to magnetic tape for input to the DMAAC Univac 1108 computer. Such tapes need to be written only once a day because of the buffer store provided by the flexible disk. This disk system has two drives.

3. Magnetic Tape System

A Data General dual-density digital magnetic tape transport, Model 6026, is used to produce a final data output tape. This tape is compatible with magnetic tape units associated with the DMAAC Univac 1108 computer. This tape transport is a 75 ips, 9-track vacuum column tape drive for half-inch magnetic tape. Data is recorded in ANSI-compatible NRZI format at 800 BPI or in ANSI-compatible Phase Encoded format at 1600 BPI. The tapes produced are widely interchangeable with other industry standard tape units.

4. Input-Output Devices

Operation of the voice VIP-100 is enhanced in the VRS-ADM by the use of several ancillary input-output devices. These devices input the speech signal, store reference data, control overall system operations and display previously inputted data.

a. Voice Input-Remote Control Unit

This module, which provides certain operator controls, is small enough to be placed in close proximity to the cartographer. The unit consists of microphone jack, microphone equalizer circuitry, and sufficient gain to transmit the audio to the preprocessor. A gain control switch normally is included in this subsystem together with a level indicator. Also included in this module is a set of three thumbwheel switches which are connected to the Nova 2 for control of training. If an operator desires to train or retrain a word, he or she sets into the switches the appropriate word number and presses a TRAIN button located on the Voice Input/Remote Control Unit. The speech preprocessor then accepts new training data and processes it such that the appropriate word reference data is stored in the Nova 2 memory.

b. Video Terminal

The basic control device for the system is a Lear Siegler

6

ADM-3A video terminal. This terminal selects the operating mode of the system and serves as an alternative to the Voice Input-Remote Control Unit for selecting words to be trained. Also, the keyboard can be used interchangeably with voice for entering DLMS cartographic data. It can display prompt messages as well as verifying input data.

c. Stereo Viewer Display

A modified Bausch and Lomb Zoom 240 stereo viewer was supplied as GFE to the contract. This device was modified by the manufacturer under a separate RADC contract. The modification consisted of adding a miniature LED 16-character alphanumeric display to the viewer. The display image is optically connected to the left eyepiece of the viewer. The display is driven by a special display interface module which includes a power switch plus a display duration control. The duration control allows the operator to limit the time duration that the message is displayed in the eyepiece. The display duration is variable from approximately 1.5 seconds to 12 seconds. A switch allows the operator to defeat duration the thereby allow the message to display indefinitely or until a new message is outputted to the display. The display interface was designed and built by TTI. This display can be used for prompt messages as well as verification of inputted data and training prompts.

d. Self-Scan Display Module

A 16-character alphanumeric display module is included as an alternate means for display of prompts and recognition results. The display also provides prompts for training. In addition to the dot matrix display characters, the operator is provided with visual READY and REJECT indicators on the display module. The READY indicator notifies the operator that the system can input and process speaker data. READY is off during certain non-speech operations such as reading or writing reference data from and to magnetic tape. The READY indicator also goes out during the time a word or phrase is being spoken. The REJECT indicator is lit when a word or noise is inputted which cannot be recognized as being a valid vocabulary word. Once REJECT is lit, it remains on until a valid word is entered or the mode of system operation is changed. An audible reject alert is included in this module.

e. Voice Response System

As an alternative method of prompting and input verification, a voice response system has been included in the VRS. The unit, a VOTRAX model ML-1, can be programmed to "say" any English word. A default vocabulary has been included in the VRS for initial experiments. The vocabulary is described in the software portion of this section.

The VOTRAX ML-1 Multi-Lingual Voice System is a solid state unit designed to synthesize human speech with unlimited vocabulary. It accepts sequences of digital word commands and converts these commands

7

into corresponding phonetic audio signals. It is an electronic simulation of the human brain-vocal system. Thus, any word in the subject language may be synthesized by a corresponding appropriate sequence of digital commands.

C. System Software

The basic DLMS data entry program structure, constructed for the VRS, has been defined according to DMA requirements as defined in "Product Specifications for Digital Landmass System (DLMS) Data Base" (first edition, July 1977). This basic program serves as the default structure which is initially active when the software is loaded into the system's Nova 2/10 computer. This data input program is referred to as the "RUN" program. However, the syntax module of the software can be easily modified by the use of a second program, referred to as the "CREATE" program. Both programs are described in the following paragraphs.

1. The RUN Program

The RUN program features a syntactic structure based upon a group of subroutines to perform a group of functions involved in data entry for the DLMS cartographic application. However, by changing the syntactic structure by the use of the CREATE program, other data entry tasks can be accomplished. The action vectors are the key to the syntactic structure. Each action vector causes execution of a specific subroutine and has been preassigned a unique letter designation or a combination of a letter and a number. These letter or letter-number combinations will be used to assign action vectors to vocabulary words with nodes. This software includes 17 action vectors. A particular action vector can be used as often as required in a complete structuring plan. Several action vectors can be associated with a particular vocabulary word within a node (syntactic) structure. For example, after a word is recognized within a node, it will usually be necessary to accomplish several functions including (1) outputting a message to the self-scan and viewer displays, (2) outputting an audible message to the VOTRAX, (3) storing the number of the recognized word in an appropriate buffer with the data field of which it is a part, (4) branching to the next node, (5) setting the node "true" or setting the node "false". The true/false designation merely means setting or resetting a node flag which can be later tested in other nodes. Each of these special action functions are activated by a separate action vector. Individual action vectors are described in Appendix B.

One action vector allows the input of restricted sets of description numbers when necessary to minimize errors. For instance, all DLMS feature identification code numbers include three digits, but not all three-digit codes are currently used by DMA. A table of up to 300 valid codes can be used to provide a means of error detection. Entries of valid code numbers are made by the use of the CREATE program. A complete table based upon the July 1977 DLMS spec has been provided. An action vector (AV=K) activates this action subroutine.

Another software feature is data editing. Anytime between the start of a data entry session and the writing to tape of the data, editing of previously inputted data will be possible. Each data field associated with a FAC number is stored temporarily in a computer memory buffer so that it may be easily retrieved for editing. This buffer is dumped onto a floppy disk when the buffer is full. It is still possible to edit data which has been stored on the floppy disk, however. To facilitate this data movement, one of the two floppy disk drives is reserved as the intermediate storage location for the DLMS data. The other drive is free to be used to input or output speaker reference (training) data or node structure data. Different disks are used for each type of data.

The data editing is as flexible as possible with the number of analyst-entered commands minimized. When an analyst needs to review previously entered data for possible errors, he or she speaks or types one of two edit commands. The FAC number of the data field is then entered by voice or keyboard and the chosen data field will be displayed on the ADM-3A CRT. The analyst has the option of changing any line by voice or by keyboard. Such changes must, of course, conform to the syntactic structure as currently implemented. After a significant amount of DLMS data has been inputted by voice, a record will be written to an output magnetic tape under the control of the analyst.

2. Data Entry Procedures With The RUN Program

The first 17 words of the vocabulary are reserved for system use. Words 0 through 9 are the digits zero through nine. Words 10 through 16 are control words. Display messages for these first 17 words cannot be modified by the user. VOTRAX messages for the digits cannot be changed. There are no VOTRAX responses for the control words, 10 through 16. The remainder of the vocabulary can be altered with regard to display and VOTRAX messages to suit the user.

Voice and keyboard entry are completely interchangeable. When entering any data by keyboard, except digits 0 through 9, a special protocol should be followed. All other vocabulary words must be spelled exactly as the display message for that word is spelled. Each word should be preceded and followed by an escape accomplished by striking the ESC key. This key will echo a "$" when struck in this manner. Any use of the RUBOUT will erase all letters and the initial escape necessitating re-entry of the escape and the complete word.

Normal data entry can be interuupted or controlled by the use of system controls which include words 10 through 16 and special keyboard inputs. The word GO (vocabulary word #10) or its keyboard counterpart, Carriage Return, is necessary after every node data input in order to progress to the next node. An exception is the use of an action vector which allows the use of another word as a "GO" command. However, when this action vector is used, the program returns to the first node in the structure rather than advancing.

The erase function is accomplished by speaking word 11, ERASE, or inputting a RUBOUT by the ADM-3A keyboard. Either erase input will delete the last data entry to a node by voice or the last digit entered by keyboard or any letters or complete word entered by keyboard. It is possible to cancel all inputs to a node by the use of the control word CANCEL (#12) or by Control X on the ADM-3A keyboard. A complete field may be cancelled by speaking the word KILL (#13) or by Control Z on the keyboard.

Data editing and writing of data to magnetic tape is also accomplished by speaking control words or by control character input to the keyboard of the ADM-3A.

3. Default RUN Program Node Structure

As mentioned before, a default node structure has been included in the RUN program software. This program is adequate for cartographic data entry under the 1977 DLMS specification. A flowchart of this structure is shown in Fig. 2. The node numbers are shown encircled. The prompt messages for each node as well as the acceptable voice or keyboard inputs and the resultant verifying display messages are shown in Fig. 3. The prompts and display messages of this structure appear on all three visual displays. In Fig. 2, the test at the output of node 8 determines whether or not the input to node 2 was the three-digit code 540. This node tests for codes 541 through 544 and for words 132 through 136. All of these feature inputs are concerned with powerlines. If a powerline feature is inputted at node 2, then node 9, "Number of Pylons" must be entered. Note that the main program branching occurs after data input to node 5, "Feature Type." The branching here is further contingent on previous inputs. The term RETURN means go back to node 1, "FAC Number" for the next data field.

Table 1 lists the visual display messages of the default node structure. Also shown are code numbers for words 17 through 21 and 23 through 247. These code numbers provide a means for alternate data entry at two nodes. Words 23 through 247 are all feature description words entered at node 2. As an alternative at this node, the associated three-digit code may be entered to this node. In either case, the actual data which is later written to tape is the three-digit code. The codes associated with the appropriate vocabulary words are necessary to allow the all-digit format of the output tape. This format is necessary because the type must be equivalent to the Opscan record which has heretofore been used to encode DLMS data for entry into the Univac 1108 central computer at DMAAC.

Because of memory limitations of the Nova 2 computer, furnished by RADC as GFE, the VRS vocabulary has been limited to 248 words. This size is not large enough to allow a vocabulary word for each node 2 feature descriptor word. Therefore, 32 feature descriptions can only be entered by the three-digit code. These 32 words are shown as a portion of the vocabulary word table and are listed opposite vocabulary word numbers 248 through 279. There are no equivalent vocabulary words for these codes.

10
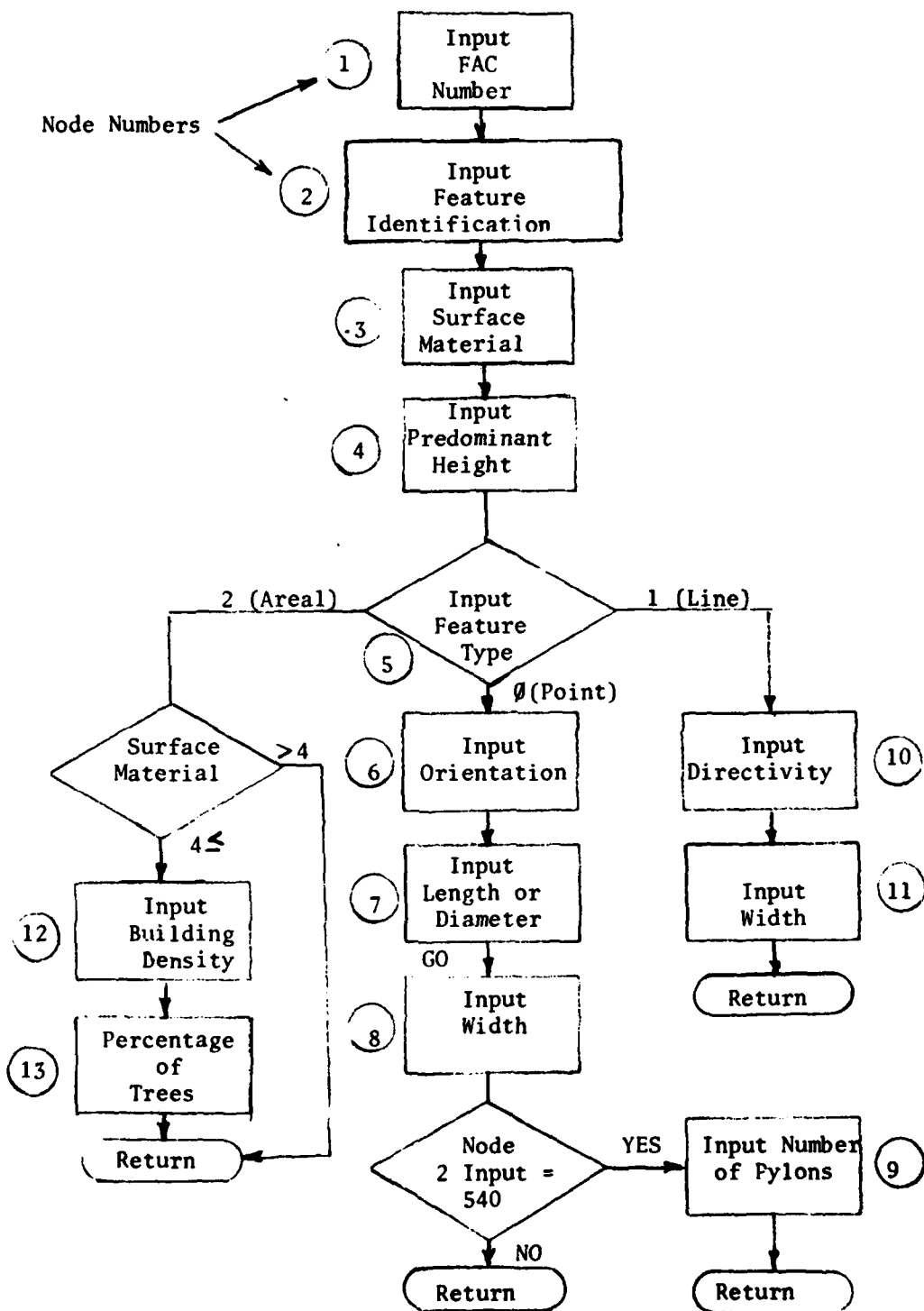
Fig. 2   Flowchart of Default Node Structure

11

NODE #	PROMPT	INPUT & DISPLAY MESSAGE
1	FAC Number	1-4 digits & GO
2	Identify Feature	Word or 3 digits & GO
3	Surface Material	Single number 1-13 & GO
4	Predom. Height	Digits & GO
5	Feature Type	Ø or 1 or 2 + GO (Ø indicates point feature) (1 indicates line feature) (2 indicates areal feature)
6	Orientation	Up to 3 digits & GO
7	Length or Dia.	Digits & GO or Digits & _Diameter_
8	Width	Digits & GO
9	Number of Pylons	Digits & GO
10	Directivity	Omnidirectional or 3 Unidirectional or 1 + GO Bidirectional or 2
11	Width	Digits & GO
12	Building Density	Single Digit & GO (Ø-13)
13	Percent of Trees	0 10 & GO 30

Figure 3 Prompt messages, acceptable inputs, and
display messages for the nodes of the
default node structure

TABLE 1   VISUAL DISPLAY MESSAGES AND FEATURE CODES SUPPLIED WITH
DLMS SYSTEM (Sheet 1)

Word #	Display Message	Code #	Word #	Display Message	Code #
0	0	-	30	PLAT W DERRICK	105
1	1	-	31	MINE SHAFT STRUC	106
2	2	-	32	PROCESSING IND	110
3	3	-	33	CHEMICAL PLANT	111
4	4	-	34	METAL PLANT	112
5	5	-	35	SEWAGE PLANT	113
6	6	-	36	EVAPORATOR MINE	114
7	7	-	37	COKE PLANT	115
8	S	-	38	BLAST FURNACE	116
9	9	-	39	REFINERY	120
10	GO	-	40	CATALYTIC CRACK	121
11	ERASE	-	41	FLARE PIPE	122
12	CANCEL	-	42	POWER PLANT	130
13	KILL	-	43	HYDROELEC PLANT	135
14	EDIT LOGICAL	-	44	THERMAL P PLANT	136
15	EDIT INDIV	-	45	TRANSFORMER YARD	137
16	WRITE M.T.	-	46	SUBSTATION	138
17	10	10	47	HVY FAB IND	150
18	11	11	48	HVY FAB FLAT	151
19	12	12	49	HVY FAB FLAT MON	152
20	13	13	50	HVY FAB GABLE	153
21	30	30	51	HVY FAB GABL MON	154
22	DIAMETER	-	52	HVY FAB SAWTOOTH	155
23	UNIDIRECTIONAL	1	53	HVY FAB CURVED	156
24	BIDIRECTIONAL	2	54	LT FAB IND	160
25	OMNIDIRECTIONAL	3	55	LT FAB FLAT	161
26	EXTRACTION IND	101	56	LT FAB FLAT MON	162
27	QUARRY	102	57	LT FAB GABLE	163
28	GAS-OIL DERRICK	103	58	LT FAB GABLE MON	164
29	OFFSHORE PLAT	104	59	LT FAB SAWTOOTH	165

13

TABLE 1 VISUAL DISPLAY MESSAGES AND FEATURE CODES SUPPLIED WITH
DLMS SYSTEM (Sheet 2)

Word #	Display Message	Code #	Word #	Display Message	Code #
60	LT FAB CURVED	166	90	SUSPENSION	261
61	DISPOSAL	170	91	CANTILEVER	262
62	SCRAP YARD	171	92	ARCH	263
63	METAL SLAG DUMP	172	93	TRUSS	264
64	WASTE PILES	173	94	MOVEABLE SPAN	265
65	STRIP MINE	174	95	BRIDGE TOWERS	266
66	BUILDING	181	96	DECK	267
67	SMOKESTACK	182	97	CONDUITS	280
68	CONVEYOR	183	98	PIPELINES	281
69	PUMPING STATION	184	99	COMMERCIAL	301
70	BRIDGE CRANE	185	100	COMM FLAT	302
71	ROTATING CRANE	186	101	COMM CIRCULAR	303
72	ROTAT CRANE TWR	187	102	COMM GABLE	304
73	COOLING TOWER	188	103	COMM CURVED	305
74	HOPPER	189	104	RECREATIONAL	320
75	DREDGE DRAGLINE	190	105	ENCLOSED STADIUM	321
76	RAILROADS	201	106	OPEN STADIUM	322
77	ELEVATED RR	202	107	DOME STADIUM	323
78	RR YARD HEAVY	203	108	GRANDSTAND	324
79	RR YARD LIGHT	204	109	ATHLETIC FIELD	325
80	RR YARD EMPTY	205	110	DISPLAY SIGNS	340
81	STOR REPAIR BLDG	220	111	BILLBOARD	341
82	RR TERMINAL BLDG	221	112	SCOREBOARD	343
83	RAILROAD STATION	222	113	HIGHWAY SIGN	344
84	RR CONTROL TWR	223	114	DRIVE IN SCREEN	352
85	ROUNDHOUSE	224	115	MULTI FAM DWELL	401
86	ROADS	240	116	APT HOTEL FLAT	402
87	ELEVATED	244	117	APT HOTEL GABLE	403
88	CAUSEWAYS	245	118	RESIDENTIAL	420
89	BRIDGES	260	119	MOBIL HOME	421

Word #	Display Message	Code #	Word #	Display Message	Code #
120	AGRICULTURAL	430	150	HOSPITAL GABLE	632
121	STOCKYARD	433	151	OBSERVATORY	640
122	WINDMILL	434	152	OBSERVATORY DOME	641
123	CEMETARY BLGS	451	153	CHURCH	650
124	COMM TWR	501	154	STEEPLE	681
125	RTV TWR TYPE A	511	155	AIRPORT AIRBASE	701
126	RTV TWR TYPE I	512	156	CONTROL TOWER	702
127	MICRO TWR TYPE A	520	157	BASE OPERATIONS	703
128	MICRO TWR TYPE I	521	158	HANGAR FLAT	704
129	MISC TWR	530	159	HANGAR CURVED	705
130	OBSERVATION TWR	531	160	RUNWAY	706
131	TWR ON STRUC	532	161	AIRCRAFT PK AREA	707
132	POWER TRANS TWR	540	162	UNI RADAR REFL	711
133	PYLON TYPE "A"	541	163	BI RADAR REFL	712
134	PYLON TYPE "H"	542	164	OMNI RADAR REFL	713
135	PYLON TYPE "I"	543	165	VOR VORTAC TACAN	714
136	PYLON TYPE "Y"	544	166	RADAR RADOME	715
137	COMM BLDG	561	167	RADAR TWR RADOME	716
138	GOVERNMENTAL	601	168	RADAR ANTENNA	717
139	CAPITAL BUILDING	602	169	RADAR TWR MT	718
140	ADMIN BLDG	603	170	RADAR VEH MT	719
141	PRISON	604	171	APPROACH LIGHTS	720
142	PALACE	605	172	RUNWAY LT SYSTEM	725
143	CASTLE	606	173	MARITIME FEATURE	750
144	INSTITUTIONAL	610	174	BREAKWATER-JETTY	751
145	SCHOOL	620	175	WHARF-PIER	752
146	SCHOOL FLAT	621	176	DRYDOCK	753
147	SCHOOL GABLE	622	177	LOCK	754
148	HOSPITAL	630	178	OFF-SHORE LOAD.	755
149	HOSPITAL FLAT	631	179	MARITIME NAV AID	760

TABLE 1 VISUAL DISPLAY MESSAGES AND FEATURE CODES SUPPLIED WITH
DLMS SYSTEM (Sheet 4)

Word #	Display Message	Code #	Word #	Display Message	Code #
180	NAV LIGHT SHIP	761	210	VEHICLE STOR	862
181	LIGHTHOUSE	765	211	VEHICLE PARK	863
182	MIL. GROUND	770	212	SHIP STOR	865
183	BARRACKS CURVED	771	213	GROUND SURFACE	901
184	BARRACKS FLAT	772	214	SOIL	902
185	BARRACKS GABLE	773	215	DESERT	906
186	GARAGE CURVED	775	216	SAND DUNES	907
187	GARAGE FLAT	776	217	MARSH-SWAMP	908
188	GARAGE GABLE	777	218	SMOOTH ROCK	910
189	DEPORT	778	219	DRY LAKE	913
190	AIRPORT ADM BLDG	791	220	MUD-TIDAL FLATS	914
191	TANKS	801	221	SURFACE FEATURE	920
192	TANK FLAT TOP	802	222	LEVEES-EMBANK	921
193	TANK DOME TOP	803	223	WALLS	922
194	TANK PEAKED TOP	804	224	CLIFFS	924
195	PEAKED TWR MT	805	225	DAMS	925
196	SPHERICAL	806	226	WATER INTAKE TWR	926
197	SPHERICAL COLUMN	807	227	FENCES	927
198	BLIMP	810	228	SALT WATER	930
199	BULLET	811	229	SALT WATER SEA	931
200	GASOMETER	812	230	S WATER SEA ICE	932
201	CLOSED STORAGE	820	231	SALT WATER ICE	933
202	SILO	821	232	FRESH WATER	940
203	GRAIN ELEVATOR	822	233	FRESH WATER SEA	941
204	GRAIN BIN	823	234	F WATER SEA ICE	942
205	WATER TWR BLDG	824	235	FRESH WATER ICE	943
206	ORDNANCE STOR	825	236	WATERFALL	944
207	OPEN STORAGE	830	237	VEGETATION	950
208	MINERAL	831	238	ORCHARDS	951
209	WAREHOUSES	861	239	DECIDUOUS TREES	952

Word #	Display Message	Code #	Word #	Display Message	Code #
240	EVERGREEN TREES	953			
241	MIXED TREES	954			
242	TUNDRA	955			
243	SNOW AREA	960			
244	PERMANENT SNOW	961			
245	PACK ICE	963			
246	POLAR ICE PACK	964			
247	REG. FEATURES	980			
248		145	264		683
289		146	265		684
250		180	266		710
251		282	267		721
252		283	268		756
253		290	269		790
254		330	270		797
255		331	271		798
256		332	272		860
257		334	273		864
258		350	274		909
259		435	275		911
260		450	276		912
261		560	277		934
262		680	278		956
263		682	279		962

This structure provides a convenient and consistent method for changing codes by the use of the CREATE program. Because all codes are associated with a word number (whether or not a vocabulary word exists) modifying the codes is a simple task. The 32 codes without equivalent descriptor words were chosen by DMA as representing infrequently used codes.

Note that many display messages are abbreviations. Because both the Self-Scan display and the Zoom 240 stereo viewer display are limited to 16 characters, it was necessary to abbreviate the longer descriptor phrases of some DLMS cultural features. The abbreviations were given to TTI by DMAAC. The VOTRAX messages which have been included with the default node structure reflect the visual message abbreviations. VOTRAX messages are not limited in length by the VOTRAX unit, but have been effectively limited by computer memory constraints.

4. The CREATE Program

The default syntactic structure included in the RUN program is adequate to perform cartographic data entry by voice or keyboard according to present DLMS specifications. However, if changes in the DLMS specifications are made in the future or if experiments are to be conducted with other types of data entry, the default node plan can easily be changed. If necessary, a completely new node plan can be structured by the user by the use of the CREATE program. Node plans once generated are stored on flexible disks for quick loading into the new program.

The CREATE program provides a means for generating not only entirely new node plans, but also new display messages and/or VOTRAX messages. It includes an editing feature which affords the user a method for making changes in an existing plan or modifying existing display or VOTRAX messages. It is also possible to print either a hard or soft copy of the node plan. This feature allows the operator to review the node plan at any time.

The most important components of a node structure are the action vectors. Action vectors are the links between node structure and RUN program subroutines. These subroutines are activated to perform specific tasks including outputting visual display messages and audible VOTRAX messages, branching to selected nodes conditioned on present or past inputs and setting software flags to allow branching later depending on present inputs. Action vectors can be associated with a complete node or with individual valid words within a node or both.

The action vectors associated with a complete node, called node action vectors, can be used to display prompt messages before an operator speaks a node-associated word so that he or she can easily be prompted through a data input task. By the use of a node action vector, it is possible to enter a node and immediately branch to another node or stay in the node entered depending on data inputted at a previous node. This

is possible because action vectors are executed in alphabetical order. Branching action vectors are executed before those for display output. If a node is entered and subsequently exited before prompt messages are issued, the operator will not be prompted by that node but by the node branched to. Normally, nodes are executed in numerical order except when branching occurs. The sequence automatically repeats after the last node in a plan has been executed.

Creating a new node plan, modifying an existing plan, or modifying display or VOTRAX messages has been facilitated by the use of an interactive dialog between the CREATE program and the person using the program. After the user selects the function to be exercised, he or she is stepped through the function by prompting questions. Error detection and correction techniques are included to warn of improper inputs.

When a node plan is to be constructed or modified, it is recommended that the complete plan be written on paper first. Inputting the plan to the computer will then be a simple interactive data entry task. A planning sheet similar to that shown in Fig. 4 can be used to facilitate the planning. One sheet should be used for each node.

The planning sheet effectively asks the questions that the CREATE program will ask via the ADM-3A video terminal. For example, the first entry for each node in a plan is the visual display prompt message, "Name of Node" on the planning sheet. Next entry is the maximum allowable number of entries to a node. The node action vectors are followed by the vocabulary for the node with the word action vectors associated with each word or group of words.

To illustrate the procedure to be followed with the CREATE program, an example is in order. In this example, the interactive process for creating the third node of the DLMS default node structure (paragraph 3 of this section) will be outlined. This node is used to input a Surface Material Code (SMC) number from 1 through 13. Also branching at node 5 can be affected by the input of this node so it is necessary to provide a means of communications between node 3 and node 5. As shown in Figure 2 (the default node structure), if the input to node 5 is the number 2 representing an areal feature, then an SMC smaller than 5 causes a branch to node 12. An SMC greater than 4 will complete the structure after node 5. A simple communication method is to set node 3 TRUE if the SMC is less than 5. This is accomplished by the use of Action Vector D.

Before entering the data for node 3 by keyboard, the CREATE Planning Sheet should be filled in by hand. Figure 5 illustrates hand entries to this sheet. The name of the node is "Surface Material". This is the prompting visual display message which the analyst will see wherever it is displayed. The maximum number of entries could be two if single digits are used. However, the default vocabulary provides the two-digit groups 10 through 13 pronounced as single words "ten" through "thirteen". These are words 17 through 20 in the vocabulary list (Table 1, Sheet 1). Therefore, the maximum number of entries can be limited to one. Next, the node action

19

```
                    DLMS CREATE PLANNING SHEET


  NAME OF NODE: __ __ __ __ __ __ __ __ __ __ __ __ __ __ __ __

  MAX. NO. OF ENTRIES:    __ __

  NODE ACTION VECTORS __$ __$ __$ __$ __$ __$ __$

    (AV Notes)




  FROM WORD  __ __ __ $    TO WORD  __ __ __ $

  WORD ACTION VECTORS __$ __$ __$ __$ __$ __$ __$

    (AV Notes)




  FROM WORD  __ __ __ $    TO WORD  __ __ __ $

  WORD ACTION VECTORS __$ __$ __$ __$ __$ __$ __$

    (AV Notes)




  FROM WORD  __ __ __ $    TO WORD  __ __ __ $

  WORD ACTION VECTORS __$ __$ __$ __$ __$ __$ __$

    (AV Notes)
```

Figure 4 Planning Sheet Example

DLMS CREATE PLANNING SHEET

NAME OF NODE: S U R F A C E   M A T E R I A L

MAX. NO. OF ENTRIES: __1__

NODE ACTION VECTORS W $ X $ Y $ Z $ __$ __$ __$

(AV Notes)

FROM WORD ___1_ $ TO WORD ___9 $

WORD ACTION VECTORS W $ X $ Y $ Z $ __$ __$ __$

(AV Notes)

FROM WORD __17 $ TO WORD __20 $

WORD ACTION VECTORS W $ X $ Y $ Z $ __$ __$ __$

(AV Notes)

FROM WORD __10 $ TO WORD __10 $

WORD ACTION VECTORS D $ __$ __$ __$ __$ __$ __$

(AV Notes)

If Input for Node 3 < Wd 5 Set
Node 3 True

Figure 5 DLMS Planning Sheet Used for Node 3 of Default Program

vectors should be noted. If the prompting messages are to be displayed on the self-scan display, on the Bausch & Lomb Zoom 240 display, and on the ADM-3A, the action vectors W, X, and Y, respectively, should be attached as node action vectors. If a prompt from the VOTRAX is desired, action vector Z should also be attached. Note that the VOTRAX message is programmed separately rather than entered into the node plan. No other node action vectors are needed for this node.

Next, the vocabulary words to be made active for this node together with the appropriate action vectors are chosen. The single digits are chosen. The single digits 1 through 9 are to be used. These digits are vocabulary words 1 through 9. It is not necessary to enter each word number of a successive set of words in the creation of a node. Rather, the limits of the set are sufficient as is shown in Figure 5. "From word 1 to word 9" defines this set of words. The action vectors to be associated with this word set are then noted. Figure 5 shows W, X, Y, and Z as action vectors. This means that the recognized word, if in this set, will be displayed on each of the three display devices and spoken by the VOTRAX for verification by the analyst. The digits "ten" through "thirteen" represented by words 17 through 20 are noted next together with the same action vectors as with the single digits.

Finally, note the means for setting the node "true" if the digit entry is less than five. Action vector D is attached to word number 10 which is the GO command. GO terminates the data entry to node 3 in the RUN program. The conditions for action vector D can be noted on the planning sheet so that the keyboard entry of the node plan will be facilitated. This note is shown at the bottom of Figure 5.

The dialog between the CREATE program and the person constructing the plan for this node is shown in Figure 6. The words and numbers which are underlined are the answers which the person constructing the node inputs by keyboard. All other words and characters shown in the figure are displayed on the ADM-3A screen by the CREATE program one line or part of a line at a time. The computer displays appropriate questions depending on previous entries. Each time an input is expected from the person constructing the node, the computer waits for a proper entry. Each entry must be separated from others in a string of multiple entries by a delimiter character.

The delimiter is the ESCAPE key on the ADM-3A keyboard. This key is echoed by a dollar sign ($) on the ADM-3A. A double entry of the ESCAPE key is necessary to terminate some entries as shown in Figure 6. On the other hand, in some instances, the ESCAPE is not echoed. For example, in the line "FROM WORD #1____ TO WORD #9____ ", the escape key must be depressed after 1 and 9, but is not echoed. In Figure 6, the underline under each number extends to the space following the number indicating that an ESCAPE was inputted although not echoed. At the bottom of this figure, an ESCAPE was inputted after "FROM WORD #" which terminated the inputs for that node and the computer immediately asked for the name of the next node.

```
NAME OF NODE
SURFACE MATERIALS
MAXIMUM NUMBER OF ENTRIES THIS NODE
1 $
NODE ACTION VECTORS
W$X$Y$Z$$
FROM WORD # 1 TO WORD # 9
WORD ACTION VECTORS
W$X$Y$Z$$
FROM WORD # 17 TO WORD # 20
WORD ACTION VECTORS
W$X$Y$Z$$
FROM WORD # 10 TO WORD # 10
WORD ACTION VECTORS
D$$
IF INPUT FOR NODE 3$LT$ WORD # 5$ SET NODE 3$ TRUE
IF INPUT FOR NODE S
FROM WORD #
NAME OF NODE
```

Figure 6   Dialog between operator and computer displayed
on ADM-3A in construction of node 3. Operator
inputs are underlined.

By the means of this interactive process, the CREATE program allows
construction of up to 50 nodes. Each node created in this manner is numbered
consecutively starting at node 1. The CREATE program also provides the
means for editing existing node plans and for changing the visual display
messages associated with vocabulary words and the message strings for the
VOTRAX.

Section III

SYSTEM ACCURACY TESTS

A.   Background

Final tests of the VRS-ADM were conducted at the TTI facility at
Delran, N.J. These tests, designed to establish system accuracy, were held
shortly before the equipment was shipped to DMAAC. The tests were
conducted by the use of tape recording of an older vocabulary for DLMS-type
applications. These recordings were made during RADC contract F30602-76-
C-0394, completed by TTI in 1978. The same data were used for the present
program in order to determine effects upon recognition accuracy of a
change in the TTI recognition algorithm since the earlier program. The
preprocessor hardware (TTI model 8040) used is the same for both programs.
Therefore, the use of the same data provided a comparison of the recognition
algorithm changes. The modified algorithm includes both linear and non-
linear correlations. It has shown increased accuracy in tests conducted
by TTI during internal research and development investigations. However, ,
it was not possible to use a key part of this algorithm for the VRS
recognition software. This portion of the modified algorithm involves
the use of probability of occurrence of preprocessor features derived in
the process of training the system for each operator's voice. The
probability measure requires twice as much computer memory space as has
been necessary before. Because of the large vocabulary for the DLMS
application, it has been necessary to delete this recognition algorithm
improvement and thereby sacrifice a measure of accuracy improvement as
will be seen by examination of test results.

The test words, previously recorded in January 1978, were arranged as
shown in Table 2. During the original test and recording session, the
test subject was instructed to read each word in this vocabulary list
exactly in the order that it appeared. This list provided inputs of each
and every word in each and every possible node of the DLMS default program
except for one node, "Percent of Trees." This node was deleted because
a large number of digits only were required by other nodes. Certain
vocabulary words occurred much more often than others in this list. For
example, each feature identifier word occurs one time, the digits 0 through
9 nine times with certain digits appearing in other nodes. This arrange-
ment simulates closely the actual vocabulary usage in an operation situation.
The difference between the vocabulary shown in Table 2 and the default
vocabulary shown in Table 1 (Section II) is in the feature descriptor
words of node 2. The tape recordings were made in January 1978 with
approximately one week between train and test data sessions for each
talker. A special node plan was constructed for this test. This plan
included the nodes indicated in Table 2 but had no branching. The GO
command was recorded on the test tapes and was required to advance
between consecutive nodes. Five training repetitions were used.

21

TABLE 2 ACCURACY TEST VOCABULARY (sheet 1)

DISPLAY PROMPTS	TEST WORDS	
FAC. NUMBER	0 through 9	
	GO	
IDENTIFY FEATURE	INDUSTRY	ELEVATED TRACK
	TRANSPORTATION	ELECTRIC RAILROAD
	COMMERCIAL	HIGHWAY
	RESIDENTIAL	ELEVATED ROAD
	COMMUNICATION	CAUSEWAY
	GOVERNMENTAL	PIPELINE
	MILITARY	ABOVE GROUND
	CIVIL	PENSTOCK
	STORAGE	BRIDGE
	LANDFORM	ROAD BRIDGE
	EXTRACTION	RAILROAD BRIDGE
	MINE	OVERPASS
	QUARRY	ROAD OVERPASS
	CONVEYOR	RAILROAD OVERPASS
	HOPPER	BUSINESS
	POWERSHOVEL	STORE
	OIL DERRICK	SHOPPING CENTER
	PROCESSING BUILDING	BANK
	PROCESSING	OFFICE
	SAWMILL	RECREATION
	COKE PLANT	STADIUM
	PETROLEUM	DRIVE-IN
	REFINERY	GRAND-STAND
	SYNTHETIC OIL	DISPLAY SIGN
	IRON SMELTER	MULTI-FAMILY
	CHIMNEY	APARTMENT
	STACK	SINGLE FAMILY
	ELECTRIC POWER	HOUSE
	COOLING TOWER	MOBILE HOME
	SEWAGE TREATMENT	AGRICULTURE
	PUMPING STATION	FARM HOUSE
	FABRICATION	BARN
	STEEL PLANT	SHED
	SHIPBUILDING	POWER
	LOCOMOTIVE MANUFACTURING	POWERLINE
	AIRCRAFT	TRANSFORMER
	MOTOR VEHICLE	SUBSTATION
	DISPOSAL	TRANSMITTING
	METAL ORE HEAP	RECEIVING
	COAL STORAGE	RADIO MAST
	SCRAP YARD	RADIO TOWER
	TAILINGS	RADAR SCREEN
	RAILROAD YARD	RADIO NAV AID
	RAIL SIDING	UNI-RADAR
	RAILROAD EMBANKMENT	BI-RADAR

22

TABLE 2   ACCURACY TEST VOCABULARY   (sheet 2)

DISPLAY PROMPTS	TEST WORDS	
IDENTIFY FEATURE (CONT'D)	OMNI RADAR	VEGETATION
	CITY HALL	MIXED WOODS
	COURT BUILDING	ORCHARD
	GOVERNMENT BUILDING	HEDGEROW
	INSTITUTION	DECIDUOUS TREES
	SCHOOL	CONIFEROUS TREES
	CHURCH	WATER
	HOSPITAL	RIVER
	AIRFIELD	LAKE
	RUNWAY	CANAL
	PARKING AREA	DRY LAKE
	PARKING LOT	WALL
	LEVEL CONCRETE	FENCE
	HANGAR	LEVEE
	TERMINAL BUILDING	EARTH EMBANKMENT
	CONTROL TOWER	SNOW
	HEADQUARTERS BUILDING	ICE
	NAVAL	CROPLAND
	SEA	GO
	WHARF	
	PIER	
	WAREHOUSE	
	BREAKWATER	
	JETTY	
	QUAY	
	PORT FACILITY	
	DAM	
	LOCK	
	LIGHT HOUSE	
	GROUND FACILITY	
	BARRACKS	
	MOTOR POOL	
	GARAGE	
	DEPOT	
	TANKS	
	PETROLEUM TANK	
	WATER TANK	
	GAS HOLDER	
	SILO	
	GRAIN ELEVATOR	
	STORAGE SILO	
	DESERT	
	ROCK	
	SAND	
	NORMAL SOIL	
	MARSH	
	SWAMP	

TABLE 2 ACCURACY TEST VOCABULARY (sheet 3)

DISPLAY PROMPTS	TEST WORDS
SURFACE MATERIAL	1 through 13 GO
PREDOM. HEIGHT	0 through 9 GO
FEATURE TYPE	0 1 2 GO
ORIENTATION	0 through 9 GO
LENGTH OR DIA.	0 through 9 GO
WIDTH	0 through 9 GO
NUMBER OF PYLONS	0 through 9 GO
DIRECTIVITY	UNIDIRECTIONAL BIDIRECTIONAL OMNIDIRECTIONAL GO
WIDTH	0 through 9 GO
BUILDING DENSITY	1 through 13 CANCEL

B.   Test Results

In the January 1978 tests, at which the recordings were made, each talker was instructed that if any word spoken was misrecognized or rejected, to repeat the word once. If the word was misrecognized or rejected again, the talker was instructed to proceed to the next word. After completion of the first pass through the list, the talker retrained with five repetitions any words which were misrecognized or rejected. The talker was then instructed to repeat the test list words following the same procedures as the first pass. Retraining after the first pass was done in order to simulate field operation of a new word recognition system. For the DLMS test, the retraining data were not used for obvious reasons. The misrecognized words of the first pass through the list in the recent test were usually not the same words as were misrecognized in 1978. A close examination of DLMS VRS test results disclosed that in only two instances was the same word misrecognized in the second pass by a talker. Also, because the test was conducted from tape, there was no opportunity to make corrections in the DLMS VRS test.

The person conducting the DLMS VRS test made a note of all dropout errors as well as substitution misrecognitions and rejects. Dropout errors occurred because of long pauses within words. Pauses, associated with stop consonants, which are greater than 150 milliseconds in length, can cause word boundary circuitry in the speech processor to indicate the end of a word at the wrong time. Quite a few more dropout errors in the DLMS VRS tests indicated a probable level difference in the tape recorder arrangement. Dropouts are related directly to the preprocessor hardware, not software,differences.

1.   Accuracy Comparisons

Accuracy test results for five talkers of the group of 10 who were involved in the January 1978 tests are shown in Table 3. Test results from those earlier tests are included for comparison. For each test, two accuracy scores were calculated. Raw scores were calculated counting all rejects and misrecognition errors. Then scores were calculated by counting only rejects and misrecognition errors remaining after the words in which dropouts occurred were discounted. Overall accuracy in the 1978 tests (old recognition algorithm) was slightly better than that achieved with the modified algorithm. As mentioned above, the complete modified algorithm could not be used because of memory limitations of the GFE Nova computer. A single talker test conducted from tape during the contract reported here showed an overall difference of 0.5 percent between the modified recognition algorithm with and without the probability measure included. This test was not exhaustive because it included the one talker speaking a short (59-word) vocabulary. It is indicative of a degradation which occurs without the probability measure.

TABLE 3 ACCURACY TEST RESULTS

Spkr.	Total Words	Previous Test					DLMS Test				
		Errors	Rejects	Drop-Outs	Raw Score %	Score w/o DO %	Errors	Rejects	Drop-Outs	Score %	Score w/o DO %
1	530	3	1	0	99.2	99.2	4	3	0	98.7	98.7
3	538	4	0	0	99.3	99.3	5	0	3	98.5	99.0
5	536	11	0	0	97.9	97.9	4	0	1	99.1	99.3
8	537	10	1	1	97.9	97.9	11	0	4	97.2	97.9
9	536	5	0	1	98.9	99.1	4	3	1	98.5	98.7
ALL	2677	33	2	2	98.6	98.8	28	6	9	98.4	98.7

NOTE: Score column w/o DO indicates accuracy not counting dropouts as errors.

2. Analysis of Errors in DLMS Test

In the 5-talker test conducted at TTI, a total of 43 misrecognitions and rejects occurred (including dropouts). These errors involved a total of 28 different words of the DLMS vocabulary of 178 words. Therefore, none of the remaining 150 vocabulary words were misrecognized for any of the five talkers. A complete list of the words which were misrecognized or rejected is shown in Table 4. The more traditional error matrix usually used for this type of illustration has been omitted because of the small portion of the total vocabulary in error. Also, a 178 by 178 matrix would be rather large. The table is divided into three sections according to the vocabulary structure.

The first field in Table 4 is the "FAC Number" field in which only digits are valid for recognition. Only one error occurred in this field for the complete talker set, a substitution of FOUR for a spoken FIVE. Each word in this field was spoken a total of 10 times in the test. The greatest number of errors occurred in the IDENTIFY FEATURE field. All except four of the vocabulary words are valid in this field. The four not valid are DIAMETER, UNDIRECTIONAL, BIDIRECTIONAL, and OMNIDIRECTIONAL. The latter three of these four words are valid under the DIRECTIVITY field. Each word in the IDENTIFY FEATURE field was spoken two times by each talker for a total of 10 times in the test.

The errors of the nine remaining fields used in the DLMS test (as shown in sheet 3 of Table 2) have been listed together because of the similarity of these fields. Each of these nine fields includes some or all of the digits 0 through 13. The total number of times each word in these fields was spoken is shown in Table 4. The number of times spoken vary from word to word because of the variations in the composition of the fields. Sheet 3 of Table 2 illustrates the construction of these fields.

The center column of Table 4 indicates words of the various fields which were spoken, but for which misrecognitions, rejects, or dropouts occurred. The righthand column indicates the misrecognitions and rejects which occurred. Rejects are indicated by "R" and dropouts by an asterisk (*) in Table 4.

Many of the errors in this test series could be expected. Substitution of ROCK for LOCK is predictable. Use of the plural for ROCK would decrease this substitution tendency. Five-Nine and Eleven-Seven confusions are also fairly common. Expected confusions such as SEA and QUAY (pronounced "key") occurred only once each way. Such confusions as QUARRY for WARF, TERMINAL for GO, and MINE for DRIVE-IN could only be ascribed to sloppy pronunciations, breath noise, or other talker problems.

27

TABLE 4 LIST OF MISRECOGNIZED WORDS
IN TESTS AT TTI

Field	Word Spoken	Word(s) Recognized	Total Reps
FAC Number	Four	Five	10
Identify Feature	Commercial	Power Shovel	10
	Electric Power	Electric Railroad	
	Railroad Embankment	* (3)	
	Elevated Track	*	
	Above Ground	Runway, *, R	
	Railroad Bridge	*	
	Road Overpass	Overpass, RR Overpass, *	
	Railroad Overpass	* (2)	
	Recreation	Fabrication	
	Drive-In	Mine	
	Barn	Mine	
	Transformer	Landform	
	Court Building	Port Facility	
	Sea	Quay	
	Warf	Quarry (2)	
	Breakwater	Grain Elevator	
	Quay	Sea	
	Lock	Rock (2)	
	Rock	Lock (4)	
	Fence	Tanks	
	Cropland	Mine	
	Go	Terminal	
Directivity	Bidirectional	Omnidirectional	10
	Omnidirectional	Bidirectional	10
(All Other Fields)	Five	Nine	80
	Six	R (2)	80
	Eleven	Five, Seven (2)	20

NOTE: R indicates reject.
* indicates dropout.

28

Section IV

CONCLUSIONS AND RECOMMENDATIONS

The major objectives of the DLMS Voice Data Entry program have been achieved. The advanced development model word recognition system developed for cartographic use during this program has been demonstrated at a recognition accuracy nearly 99 percent by experienced talkers. The operational VRS capability which has been developed is suitable for entering Digital Landmass System (DLMS) data at DMAAC. This VRS system has the capability of recognizing up to 248 separate words in syntactic structures. A software operating system is included with the hardware to allow changes in the syntactic structure as DLMS requirements change. A default program structure has been constructed which is based upon the DMA publication, "Production Specifications for Digital Landmass System (DLMS) Data Base", dated July 1977.

The system includes the capability for remote training by any speaker of any word or a complete vocabulary of words for a cartographic data input task. Response time of the system to any word in any vocabulary is less than 0.25 seconds. This fast response to large vocabulary sets is due partly to the use of a TTI hardware high-speed correlator which is an integral part of the system hardware. Provision for storing large numbers of complete data fields for the DLMS applications has been made. An operator can recall such stored data for review and modification when necessary. A digital magnetic tape unit provides a bulk data output means for interfacing with the DMAAC Univac 1108 central computer. Operator speaker reference data as well as syntactic structure data (node plans) are stored on flexible disks. Flexible disks are also used for data buffer storage. Three visual and one aural feedback means are part of the VRS.

The VRS has been installed at the Defense Mapping Agency in St. Louis by TTI. Training was conducted for DMA personnel in the various aspects of system operation. TTI now recommends a period of operational evaluation in which the VRS is used for input of DLMS cultural data by analysts. Initial tests could last for 20 to 30 working days. The two data entry methods available with the VRS, voice and keyboard, can be evaluated together with traditional manual FADT or Opscan input. This evaluation should include entry time and the number of errors detected by the validation program currently in use following manual data entry. The time required to correct errors should also be evaluated. The analysts' preference for each of the four methods of feedback should be noted. The effect upon data input efficiency can be determined for each feedback method. Also, the possible deleterious effects of the display in the eyepiece of the Bausch & Lomb stereoscope can be evaluated.

After the initial test series, an optimum system configuration could be implemented in hardware and software. Such a configuration should then be tested over a longer period, perhaps 60-90 days with monitoring of results at periodic intervals.

APPENDIX A

A Multi-Station Cartographic Voice Data Entry System

An engineering development model voice data entry system (VDES) could be most efficiently implemented in a multi-station configuration. The block diagram shown in Figure A-1 is a possible configuration of such a system. The upper portion of this block diagram shows one of up to eight input stations which could be located remotely from the central processor section shown in the lower part of the Figure. This configuration is basically similar to those of several other TTI multi-station systems built for commercial applications. Most of the system components are shown with exact manufacturer part or model number. Certain system components would merit special evaluation. For example, no part or manufacturer is associated with the voice response unit. The usefulness of voice response for prompting and input verification should be carefully considered in future tests. A VOTRAX voice response synthesizer is included in the cartographic VRS developed under this program for DMAAC by TTI. This unit, which is relatively expensive, may not be the best approach to voice response generation.

Another area meriting special study is the Zoom 240 eyepiece display. The display developed by Bausch & Lomb and interfaced by TTI with the current cartographic VRS is somewhat cumbersome and may cause problems associated with the intensity of the image. Also, in the current configuration, the Zoom 240 display interface is a slave to the self-scan display module. In a multi-station system, it is likely that a direct connection to the multiplexor would be preferable. Another consideration is the likely replacement of the Zoom 240 with an improved device, the Zoom 500.

An important consideration in the proposed system is the maximum number of input stations that can be included in a multi-station system. TTI has found that a system based on a Nova 3 or similar computer operating with RDOS or similar operating system has a practical upper bound of eight or nine. By the use of a large computer such as a Data General Eclipse with an operating system such as Data General's AOS, this number can be significantly increased.

An important feature of the software for such a system should be the greatly expanded use of error detection and correction. A limited measure of error detection is included in the DLMS VRS reported herein. However, the use of an operating system such as RDOS with a large disk memory allows a very sophisticated error detection and correction scheme to be implemented.
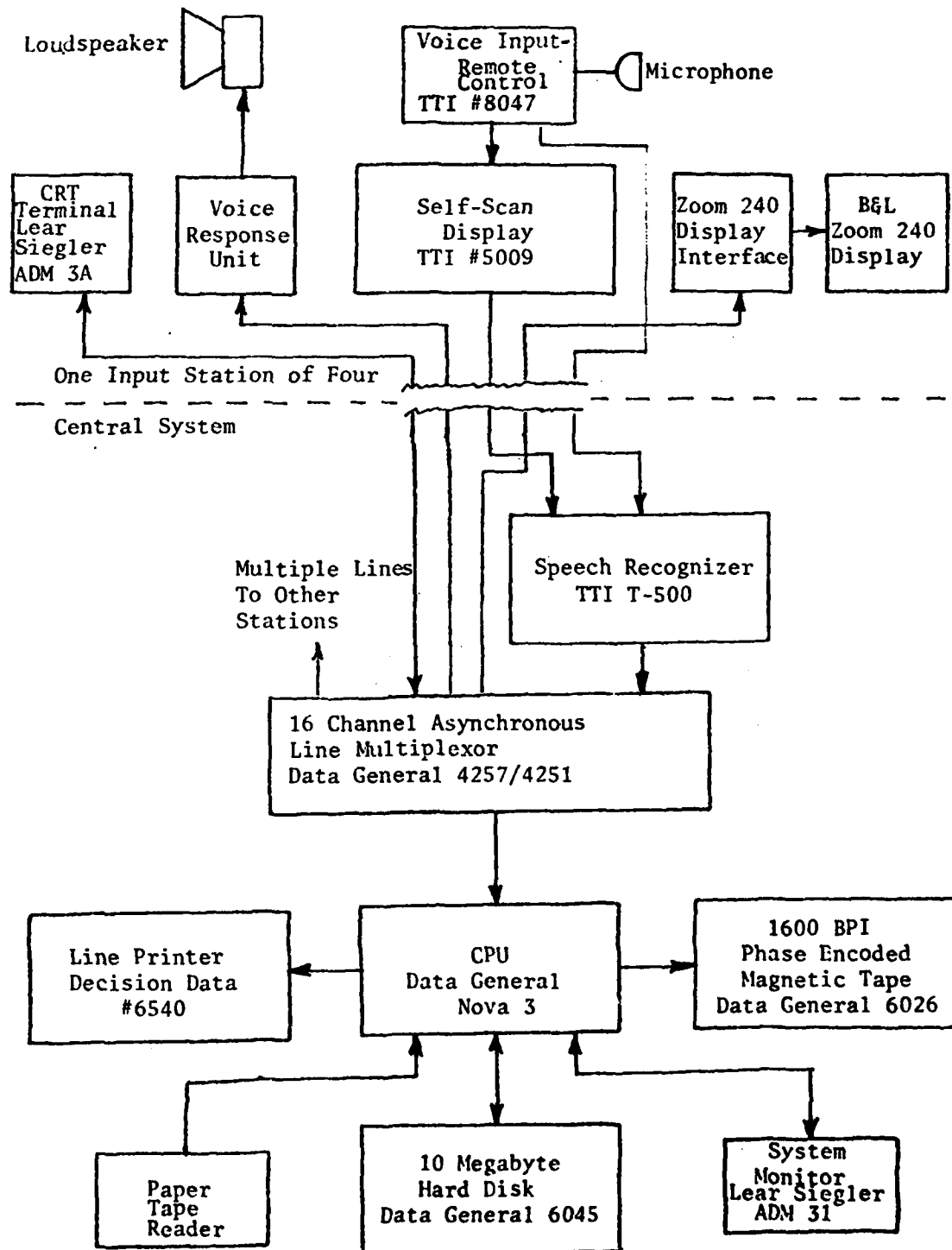
Loudspeaker

Voice Input-
Remote
Control
TTI #8047 — Microphone

CRT
Terminal
Lear
Siegler
ADM 3A

Voice
Response
Unit

Self-Scan
Display
TTI #5009

Zoom 240
Display
Interface

B&L
Zoom 240
Display

One Input Station of Four

Central System

Multiple Lines
To Other
Stations

Speech Recognizer
TTI T-500

16 Channel Asynchronous
Line Multiplexor
Data General 4257/4251

Line Printer
Decision Data
#6540

CPU
Data General
Nova 3

1600 BPI
Phase Encoded
Magnetic Tape
Data General 6026

Paper
Tape
Reader

10 Megabyte
Hard Disk
Data General 6045

System
Monitor
Lear Siegler
ADM 31

Fig. A-1 Possible Hardware Configuration for a
Multistation Cartographic VDES

31

ACTION VECTOR DESCRIPTIONS

The following is a set of action vector descriptions. There are
17 action vectors now available, 15 of which are designated by a single
letter with two letter number combinations.

1. Conventions

Expressions enclosed in brackets indicate variables which are inputted
by the operator. "Logical Expression" is one of the following:

> EQ - Equals
>
> GT - Greater than
>
> LT - Less than
>
> GE - Greater than or equal
>
> LE - Less than or equal

String is a set of ASCII characters. The maximum number of characters
in a string is 4.

WD# is a number which corresponds to a word defined in the vocabulary.
X, Y, Z are node numbers. The digits are words $\emptyset$ through 9.

2. Individual Action Vector Descriptions

> a. Action Vector - A:
>
> > If input for Node (X) (logical expression)
> > (string) branch to Node (Y).
>
> b. Action Vector - B:
>
> > If input for Node (X) (logical expression)
> > (WD #) branch to Node (Y).
>
> c. Action Vector - C:
>
> > If input for (X) (logical expression) (string)
> > Set Node (Y) TRUE else set FALSE.
>
> d. Action Vector - D:
>
> > If input for Node (X) (logical expression) (WD #)
> > Set Node (Y) TRUE else set FALSE.

e. Action Vector - E:

If Node (X) TRUE branch to Node (Y).

f. Action Vector - F:

If Node (X) FALSE branch to Node (Y).

g. Action Vector - G:

If input for Node (X) (logical expression) (string)
Branch to Node (Y) else branch to Node (Z).

h. Action Vector - H:

If input for Node (X) (logical expression) (WD #)
  Branch to Node (Y) else branch to Node (Z).

i. Action Vector - I:

If previous inputs to Node (X) (logical expression)
(string) Don't accept current input.

j. Action Vector - J:

If previous input to Node (X) (logical expression)
(WD#) Don't accept current input.

k. Action Vector - K:

Validate a three digit input against the number code list.

l. Action Vector - W:

Output string to Self-Scan display.

m. Action Vector - X:

Output string to B + L Zoom 240 display.

n. Action Vector - Y:

Output string to ADM-3A CRT terminal.

o. Action Vector - Z:

Output to VOTRAX.

p. Action Vector - A1

Return to Node 1 (unconditionally)

q. Action Vector A6

Process WD#(s) as the "GO" function and go to Node 1

Appendix C

CREATE PROGRAM DESCRIPTION

The CREATE portion of the DLMS program consists of eleven separate routines. When the program is being run, a menu is displayed on the ADM-3A CRT from which the operator can make a selection.

Once the operator has inputted a selection via the ADM-3A keyboard, the program utilizes a jump table to calculate the address (location) of the selected routine. When the selected routine has been completed, the program again displays the menu allowing the operator to make another selection. The principal routine of the CREATE program is the node plan creation routine. This routine is described in the following paragraphs and in the accompanying flowchart group.

Creating the node plan is a repetitive process whereby the operator continues inputting from the ADM-3A keyboard until the desired number of nodes has been created. Once a node has been created, the program merely returns to the beginning and awaits operator input for the next node.

The node plan is a table of data that is constructed by the operator replying to queries displayed on the ADM-3A CRT. The length of the table varies depending upon the number of nodes created. A maximum of fifty nodes is permitted.

In general, most incorrect operator inputs will be flagged, and an error message will be displayed on the ADM-3A CRT indicating the nature of the error.

Upon invoking the CREATE routine, the following query is displayed on the ADM-3A CRT:

NAME OF NODE

In response to the query, the operator may input as many as sixteen characters for the node name.

EX: FAC NUMBER

The routine check to determine if the input was a double (two) escape since inputting a double escape in place of the node name is the only way an operator is able to exit the routine and return to the calling routine.

Should the operator not elect to exit the routine, the node name is stored in the table, and the next query is displayed on the ADM-3A CRT.

MAXIMUM NUMBER OF ENTRIES THIS NODE

The operator's input is checked to determine if the input is a digit. Any character other than a digit is flagged with the error message INCORRECT INPUT, and the query is once again displayed.

Next, the following message is displayed:

NODE ACTION VECTOR

Again, the input is checked for validity. An invalid input will elicit an error message. More than one error has been defined for the action vector input; hence, the error message depends upon the error detected.

A double escape terminates action vector input. Associated with most of the action vectors is a set of specifications. The specifications are unique with respect to the action vectors; therefore, each action vector will elicit its own queries to which the operator should reply. Appropriate error checks and messages are utilized to assist the operator.

Next, the word numbers are inputted. Since word numbers are inputted in pairs, the following queries are displayed:

FROM WORD #

At this point, the operator inputs the first word of the word pair. If an escape is inputted in place of word number, the routine terminates the creation of the current node, returns to the beginning, and attempts to create the next node. Otherwise, the routine checks the input for validity. Invalid inputs elicit an error message and the query FROM WORD # is again displayed.

Having detected a valid input, the routine displays the following query:

TO WORD #

Inputting an escape causes the program to accept as input the same number that was inputted for the first word number; therefore, the program checks to determine if an escape was inputted. Not finding an escape causes the program to check the validity of the input. An incorrect input is flagged with the appropriate error message.

Once the word pair has been entered correctly, the following query is displayed on the ADM-3A CRT:

WORD ACTION VECTORS

Invalid inputs are flagged with an error message. A double escape causes the routine to ask for the next word pair, whereas a valid input causes the routine to display queries for the action vector specifications.
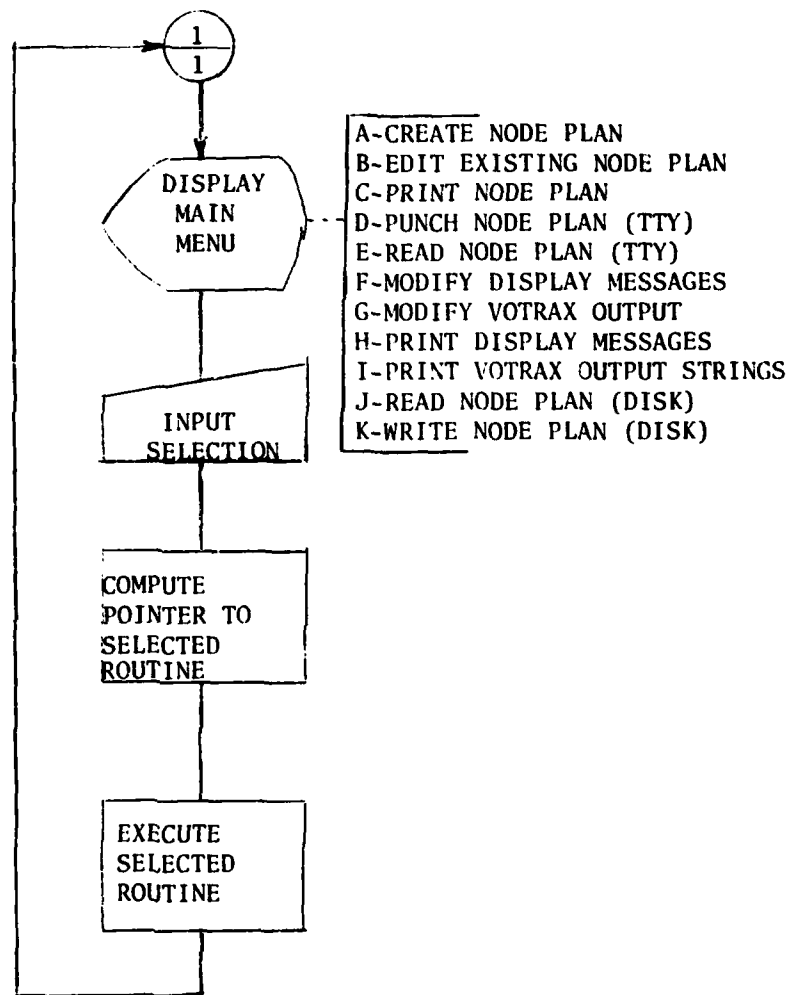
```
         ┌───┐
         │ 1 │
         │ 1 │
         └───┘
           │
           ▼
      ╱───────────╲
      │  DISPLAY   │          A-CREATE NODE PLAN
      │   MAIN     │─ ─ ─     B-EDIT EXISTING NODE PLAN
      │   MENU     │          C-PRINT NODE PLAN
      ╲───────────╱           D-PUNCH NODE PLAN (TTY)
           │                  E-READ NODE PLAN (TTY)
           │                  F-MODIFY DISPLAY MESSAGES
           │                  G-MODIFY VOTRAX OUTPUT
           │                  H-PRINT DISPLAY MESSAGES
           │                  I-PRINT VOTRAX OUTPUT STRINGS
      ┌───────────┐           J-READ NODE PLAN (DISK)
      │  INPUT     │          K-WRITE NODE PLAN (DISK)
      │ SELECTION  │
      └───────────┘
           │
           ▼
      ┌───────────┐
      │ COMPUTE    │
      │ POINTER TO │
      │ SELECTED   │
      │ ROUTINE    │
      └───────────┘
           │
           ▼
      ┌───────────┐
      │ EXECUTE    │
      │ SELECTED   │
      │ ROUTINE    │
      └───────────┘
```

Figure C-1 CREATE Routine Flowchart
(Page 1 of 6)

Figure C-1   CREATE Routine Flowchart
(Page 2 of 6)

1/2

VALID INPUT

NO

"INCORRECT INPUT"

YES

2/2

"NODE ACTION VECTORS"

INPUT NODE ACTION VECTOR

DISPLAY ERROR MESSAGE
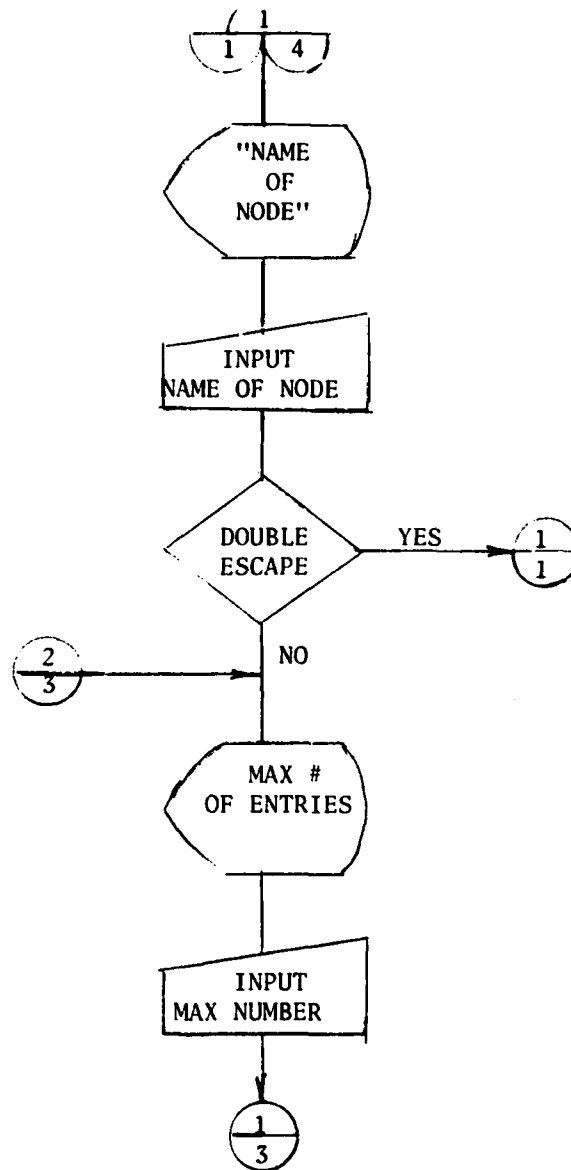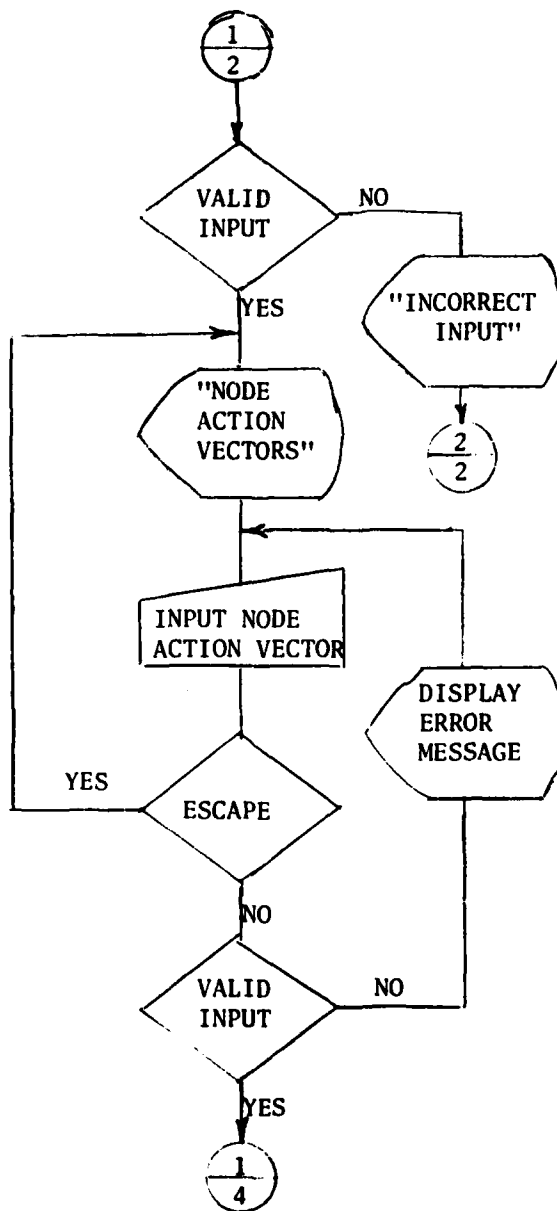
YES

ESCAPE

NO

VALID INPUT

NO

YES

1/4

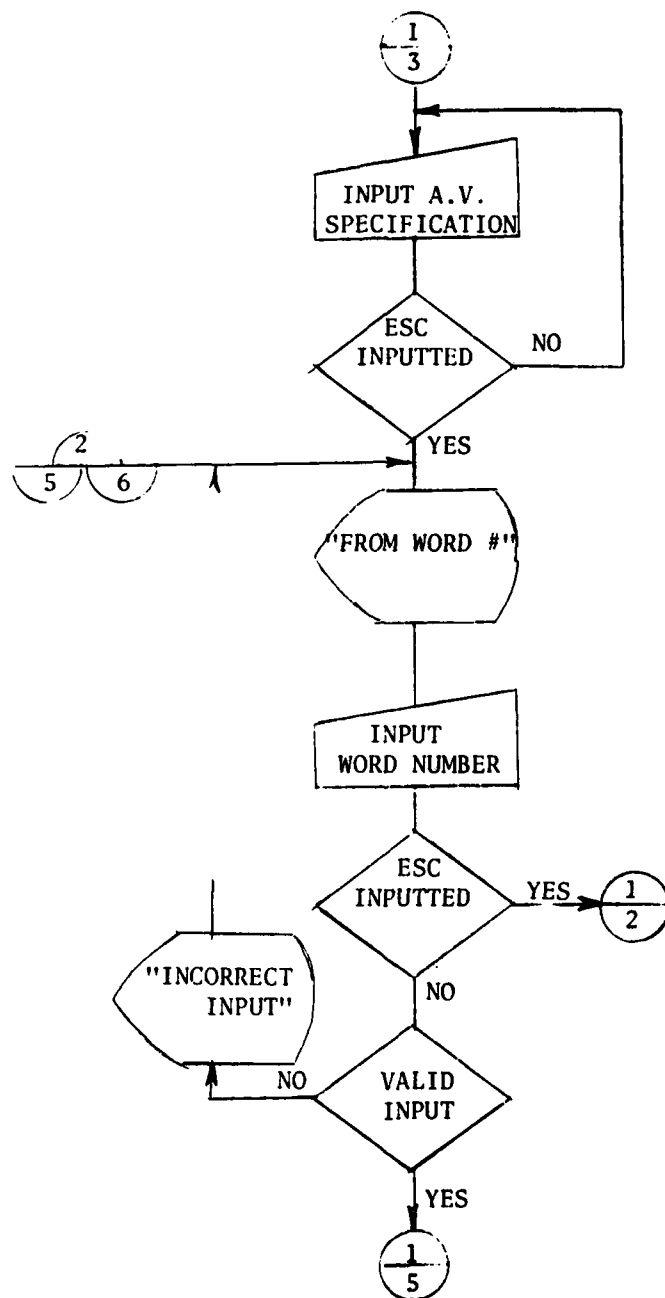Figure C-1   CREATE Routine Flowchart
(Page 3 of 6)

Figure C-1   CREATE Routine Flowchart
(Page 4 of 6)
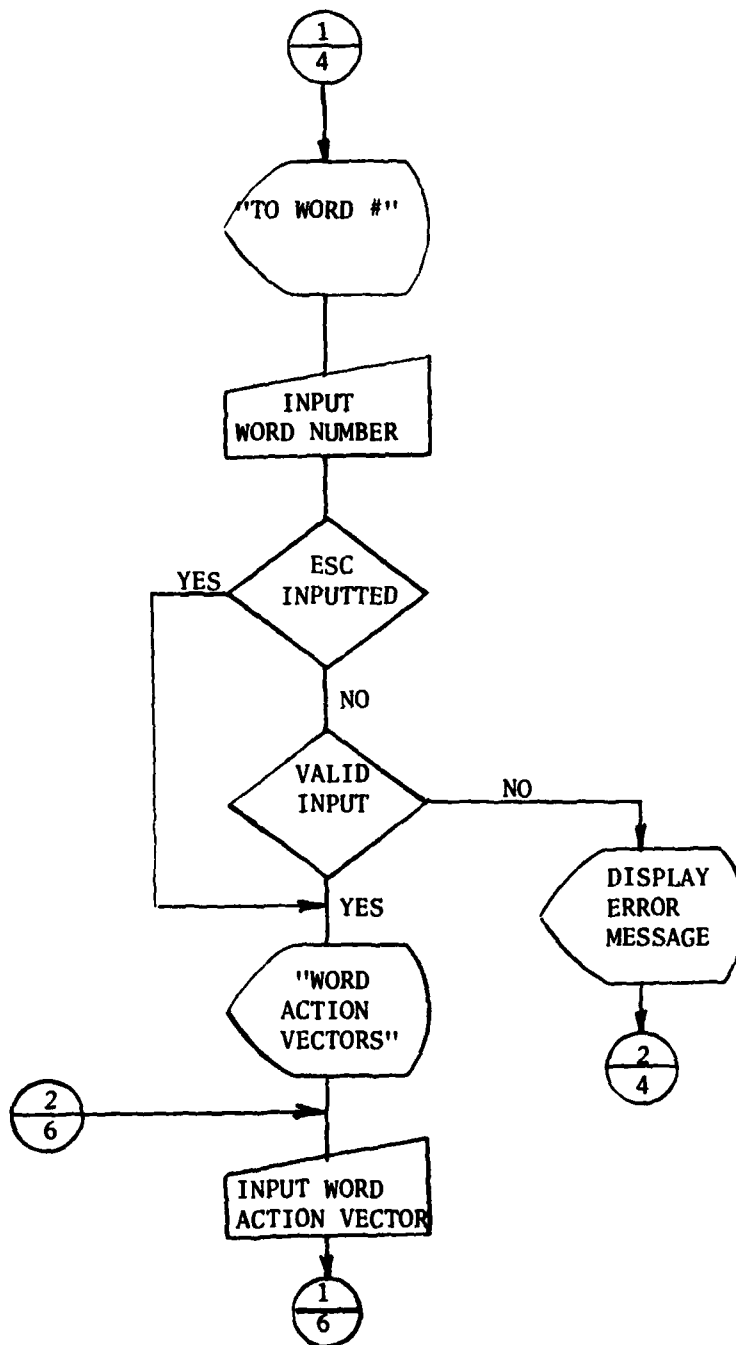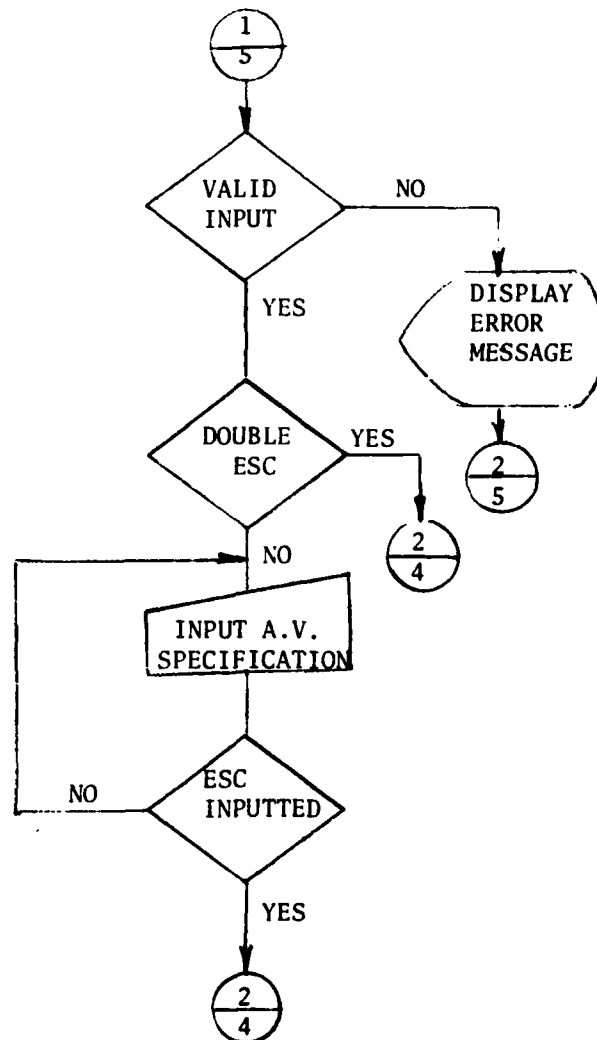
Figure C-1   CREATE Routine Flowchart
(Page 5 of 6)

Figure C-1   CREATE Routine Flowchart
(Page 6 of 6)

41